A preliminary assessment of using conservation drones for Sumatran orang-utan (Pongo abelii) distribution and density

Wich, Serge ; Dellatore, David ; Houghton, Max ; Ardi, Rio ; Koh, Lian Pin

Abstract: To conserve biodiversity, scientists monitor wildlife populations and their habitats. Current methods have constraints, such as the costs of ground or aerial surveys, limited resolution of freely available satellite images, and expensive high-resolution satellite images. Recently researchers started to use unmanned aerial vehicles (UAVs or drones) for wildlife and habitat monitoring. Here we tested whether we could detect nests of the critically endangered Sumatran orang-utan on imagery acquired from a camera-mounted drone to determine distribution and density. Our results show that the distribution of nests compares well between aerial and ground-based surveys and that relative density (nest/km) shows a significant correlation between these two survey types. The results also indicate that both methods can be used to detect significant differences in relative density between previously degraded reforested and enriched areas. We conclude that orang-utan nest surveys from drones are a promising survey method to determine distribution and (relative) density of Sumatran orang-utans and perhaps other ape species.

DOI: https://doi.org/10.1139/juvs-2015-0015

Originally published at:
Wich, Serge; Dellatore, David; Houghton, Max; Ardi, Rio; Koh, Lian Pin (2016). A preliminary assessment of using conservation drones for Sumatran orang-utan (Pongo abelii) distribution and density. Journal of Unmanned Vehicle Systems, 4(1):45-52.
DOI: https://doi.org/10.1139/juvs-2015-0015

Canadian Science Publishing
NRC Research Press journals | Publishing Services
Journal of Unmanned Vehicle Systems
Revue des systèmes de véhicules télécommandés

A preliminary assessment of using conservation drones for Sumatran orang-utan (Pongo abelii) distribution and density

Journal:	*Journal of Unmanned Vehicle Systems*
Manuscript ID	juvs-2015-0015.R1
Manuscript Type:	Article
Date Submitted by the Author:	04-Sep-2015
Complete List of Authors:	Wich, Serge; Liverpool John Moores University, School of Natural Sciences and Psychology Dellatore, David; Sumatran Orangutan Society, Houghton, Max; Liverpool John Moores University, Ardi, Rio; Yayasan Orangutan Sumatera Lestari, Koh, Lian Pin; University of Adelaide,
Keyword:	UAV, Drone, remote sensing, great apes

A preliminary assessment of using conservation drones for Sumatran orang-utan (*Pongo abelii*) distribution and density

Serge Wich[1,2], David Dellatore[3,4], Max Houghton[1], Rio Ardi[5], and Lian Pin Koh[6]

[1]Research Centre in Evolutionary Anthropology, and Palaeoecology, School of Natural Sciences and Psychology, Liverpool John Moores University, Byrom Street, Liverpool L3 3AF, UK

[2]Institute for Biodiversity and Ecosystem Dynamics, University of Amsterdam, Sciencepark 904, Amsterdam 1098, the Netherlands

[3]Sumatran Orangutan Society, The Old Music Hall, 106-108 Cowley Road, Oxford OX4 1JE

[4]Anthropological Institute and Museum, University of Zurich, Winterthurerstrasse 190, CH-8057 Zürich

[5]Yayasan Orangutan Sumatera Lestari – Orangutan Information Centre, Jl Bunga Sedap Malam 18c no.10, Medan 20131, North Sumatera, Indonesia

[6]Environment Institute, and School of Biological Sciences, The University of Adelaide, Adelaide, South Australia 5005, Australia

Abstract

To conserve biodiversity scientists monitor wildlife and their habitats. Current methods to do so have constraints such as costs of ground or aerial surveys, limited resolution of freely-available satellite images, and high costs of high resolution satellite images. Recently researchers started to use unmanned aerial vehicles (aka drones) for wildlife and habitat monitoring. Here we tested whether we could detect nest of the critically endangered Sumatran orang-utan on images acquired from a camera on a drone to determine distribution and density. Our results show that the distribution of nests compares well between aerial and ground surveys and that relative density (nest/km) show a significant correlation between aerial and ground surveys. The results also indicate that both methods can be used to detect significant differences in relative density between reforested and enriched areas. We conclude that orang-utan nest surveys from drones are a promising survey method to determine distribution and (relative) density of this ape.

Introduction

A central task of conservation science is the monitoring of species' abundance and their habitat. Generally species monitoring is conducted by surveys on the ground or from small manned airplanes (Buckland *et al.* 1993; Buckland *et al.* 2004). Ground surveys are often costly and take considerable effort when areas are large. Aerial surveys have the advantage of being able to cover large areas, but are often very costly, risky due to crashes (Sasse 2003), not always possible due to unavailability of planes or helicopter, and cannot be used for species under thick vegetation.

Habitat monitoring is often undertaken by a combination of ground-truthing and land-cover classification on medium resolution satellite images that are freely available (Hansen *et al.* 2013). The advantage of this approach is that large areas can be classified, however due to the medium resolution of the freely available satellite images not all land-covers can be classified accurately. Differences between logged and unlogged forests for example are very subtle and thus are practically undetectable (Szantoi *et al.* in review). In addition, some areas in the tropics often have cloud cover which can interfere with obtaining a clear satellite image.

Because of the reasons stated above, conservation workers have recently started to use unmanned aerial vehicles or drones (hereafter drones) for wildlife surveys and habitat monitoring. Drones have been used for a variety of wildlife distribution and density studies ranging from terrestrial to marine species. In addition studies have assessed species in a variety of habitats ranging from more open savannahs to dense tropical rainforests. (Jones, Pearlstine & Percival 2006; Koski, Abgrall & Yazvenko 2010; Getzin, Wiegand & Schöning 2012; Koh & Wich 2012; Anderson & Gaston 2013; Hodgson, Kelly & Peel 2013; Vermeulen *et al.* 2013; Chabot, Carignan & Bird 2014).

In this paper the focus is on preliminary data that were gathered to assess the usefulness of drones in determining Sumatran orang-utan distribution and density. Sumatran orang-utans are a critically endangered great ape species that has seen a huge decline over the past decades as a result of habitat loss and degradation (van Schaik, Monk & Robertson 2001; Wich *et al.* 2008; Wich *et al.* 2011; Wich *et al.* 2012). Traditionally orang-utan distribution and density are assessed by conducting linear transects and counting their nests along the transect (van Schaik, Priatna & Priatna 1995; Buij *et al.* 2003). On average an adult Sumatran orang-utan builds a nest between 1.7-1.9 times a day for resting during midday and at night. These nests can be constructed at different positions in a tree such as on top of the canopy, inside the canopy close to the trunk, and on a large branch (Buij et al. 2003). This method is expensive and time-consuming due to the relatively large areas that orang-utans occur in and the difficulty of the often mountainous or swamp terrain in which they occur. Studies have shown that human observers can detect orang-utan nests from manned helicopters (Ancrenaz *et al.* 2005) and that birds nests can be observed from drones (Mulero-Pázmány, Negro & Ferrer 2014). Therefore~~and so~~ we aimed to determine whether the distribution and relative abundance of orang-utan nests could be derived from images acquired from a camera attached to a drone.

Methods

This study was conducted in October and November 2013 in the Leuser Ecosystem, in North Sumatra, Indonesia (Fig 1). The research area consisted of a formerly cleared area that has been reforested in various years since 2008, with selectively logged forest to the south of those areas that were illegally cleared by two local plantation companies and planted with oil palm (Fig 2).

Ground surveys

To determine orang-utan distribution and relative density 16 transects randomly planned in the area using the design function in Distance 6.2 (Thomas et al. 2010). Transects had varying lengths with a mean of 0.8km (sd = 0.5). Along each transect two experienced observers walked slowly and recorded the perpendicular distances of all identified nests from the transect line (Fig 3). Perpendicular distances were measured with a rangefinder or measuring tape. For comparisons between the regenerated forests of different ages, transects were split into 5 transects for the area planted in 2008, 6 transects for 2009, 2 for 2010, 4 for 2011, 11 for 2013, and 8 in the slightly less degraded area that only underwent enrichment planting (~400 seedlings planted per hectare instead of ~1,100+).

Aerial surveys

We flew over the ground transects with a Skywalker 2013 drone that used a HK 2.7 autopilot. For ground control software we used the mission planner software (http://planner.ardupilot.com/) on a standard windows-based laptop. Two types of missions were conducted: nest transects and mapping. For the transect missions the exact same coordinates of the ground transects were used to program the missions. We flew two missions to cover all nests and fly at 80m above ground level (agl). For the mapping missions we flew a lawnmower pattern mission over the whole study area at 150m agl.

The drone was equipped with a top forward facing Canon S100 camera with a Canon Hack Development Kit (CHDK: http://chdk.wikia.com/wiki/CHDK) firmware enhancement that allows for additional functionality, which in this case was using a script that allowed for images taken at 2 seconds interval. Images were obtained without using the zoom function on the camera.

Orthomosaic

The internal GPS of the camera was used to geotag the images. A total of 2238 images were used to produce a 5.22 km^2 orthomosaic with a ground resolution of 5.36cm/pixel side. The orthomosaic was produced with the Pix4Dmapper software (https://pix4d.com/).

Nest detection

Two observers manually examined the nest transect images for nests (Fig 3) and subsequently the location of the nest could then be determined on the orthomosaic.

To be able to compare the relative density of nests from the air and from the ground we only included nests from the air that were within the maximum perpendicular distance at which nests were seen on the ground (25m).

Data analyses

The data were not normally distributed so non-parametric analyses were applied. All analyses were conducted in R and ArcGIS. Medians and 25^{th} and 75^{th} percentiles are presented where applicable. For analyses comparing the nest densities between areas, the transects that covered more than one area were split into sub-transects that only covered one particular area. Therefore the sample size on those tests is larger than the initial number of transects. The Kernel Density Estimation (KDE) tool within the Spatial Analysis extension for ArcGIS ArcMap was used to determine areas of detected nest concentration. Kruskall-Wallis post-hoc comparisons were adjusted using the Dunn-Sida~~e~~k procedure (Dunn 1964).

Results

The number of nests that were observed along transects during ground surveys varied from 0/km to 36.7/km (median = 11.5/km; 0, 11.68; n = 16). The aerial surveys also showed a highly variable number of nests that ranged from 0/km to 10.7/km (median = 0.5/km; 0, 1.63; n = 16). As expected the number of nests observed per kilometre surveyed was significantly higher in ground than aerial surveys (Wilcoxon-signed rank test: v = 36; p = 0.014; n = 16) and overall the number of nests found during aerial surveys was 17.4% of the nests found during the ground surveys. But the number of nests per kilometre surveyed showed a significant correlation between ground and aerial surveys (Spearman's rho = 0.89; p < 0.0001; n = 16).

The number of ground nests/km varied significantly between the different areas (Kruskall-Wallis test: $X^2 = 14.50$, df = 5, p = 0.013, Fig 4~~3~~). Post-hoc tests showed that the number of nests/km is significantly higher in the enriched area than the area replanted in 2008 (p = 0.04). A similar significant pattern was found for aerial nests/km (Kruskall-Wallis test: $X^2 = 23.89$, df = 5, p < 0.001). Here post-hoc tests again showed that the enriched area had significantly more nests than the area reforested in 2008 (p = 0.008), but also more than in the area reforested in 2011 (p = 0.04) and 2013 (p < 0.001).

We calculated Kernel distributions for both the ground and aerial nests to obtain an impression of the areas where most nests were found and how they compared between the ground and aerial surveys. Although no formal comparison of the distributions was attempted figure 5~~4~~ shows that the distributions are similar.

Discussion

This preliminary study shows that orang-utan nests can be detected from the air using a small drone with a standard consumer-grade camera. Although the number of nest/km were significantly higher for the ground surveys than the aerial surveys the results show that the number of nests observed during ground and aerial surveys is significantly correlated. In general, both survey methods detected more nests in the area that only underwent enrichment planting than in the other areas that were fully replanted with indigenous forest tree species. Although no formal testing was conducted the nest distributions of ground and aerial nests seems comparable.

The current study provides evidence that orang-utan nests can be detected from still images obtained from a UAV. During aerial surveys with manned aircraft it was possible to correlate aerial nest data to ground nest survey data and derive orang-utan densities from those (Ancrenaz *et al.* 2005). We have not yet tested that for orang-utans, but the fact that the number of nests/km did correlate significantly between ground and aerial surveys indicates that aerial surveys for orang-utan nests from UAVs might also allow for density estimates. Caution is needed here though because the number of nests detected per transect during the UAV survey was much lower than those from the ground survey per transect. It could potentially be that therefore UAV surveys lead to higher number of transects with zero nests than ground surveys, which could influence density estimates in a way that is difficult to correct for. During this study we detected nests in the aerial surveys for all ground transects except for one in which only one nest was found on the ground transect so potentially there is not a concern. More comparative studies are needed to determine whether transect with low nest numbers in ground surveys often have no nests in the aerial survey.

T~~Furthermore t~~he nest density distribution maps showed similarity in distribution between the ground and aerial nest densities. Future studies are currently underway to assess in detail whether orang-utan nest density can be directly derived from aerial images obtained from a UAV.

These results corroborate recent findings from another study that used drones to detect nests made by chimpanzees (*Pan troglodytes*)(van Andel *et al.* in review). Because in some chimpanzee populations there is a varying proportion of nests build on the ground (Koops *et al.* 2007) estimating density is potentially challenging and would need to incorporate location specific parameters. These findings suggest that drones can also be used to determine the distribution and potentially density of other great apes such as gorillas (*Gorilla* sp) and bonobos (*Pan paniscus*).

The overall effectiveness of using drones for great ape surveys and in general for wildlife survey work depends on whether the large number of still images need to be assessed manually for the presence of nests or whether this can be done via computer vision algorithms that detect nests automatically. An early pilot on this for orang-utan nests showed promising results (Chen *et al.* 2014), but more research need to be conducted to develop a user-friendly program that can detect ape nests.

~~Although ground transects were not established in the oil-palm plantations that remain adjacent to the study area, the aerial surveys did fly over parts of these plantations, but we were unable to detect any nests in the oil palms. Even though coverage of oil-palm plantations from the air was not extensive it was expected that we would find some nests in the area if orang-utans were using these areas to pass through or feed in as has been observed in Borneo (Ancrenaz *et al.* 2014). This might further support the hypothesis that except for rare cases (Campbell-Smith *et al.* 2011a; Campbell-Smith *et al.* 2011b) Sumatran orang-utans do not venture in to agricultural areas. This stands in contrast to orang-utans in Borneo (*Pongo pygmaeus*) that are found in areas that are dominated by pulp and paper plantations (Meijaard *et al.* 2010).~~

An important next step is to carefully evaluate the full costs of using drones for these surveys compared to ground surveys. Such comparisons need to not only take equipment and survey time into account, but also man-hours analysing data. Such comparisons are necessary for wildlife surveys in general (Vermeulen *et al.* 2013).

In conclusion, using drones for orang-utan nest detection seems feasible to determine their distribution and relative density in the three land covers we assessed, but more studies need to be conducted to determine their applicability for estimating orang-utan density.

Acknowledgements

Processed with Pix4Dmapper by Pix4D. Financial support was provided by Chester Zoo and The Orangutan Project. LPK was supported by the Australian Research Council. We thank Keeyen Pang and Ryan Pang of Hornbillsurveys for conducting the flights.

References

Ancrenaz, M., Gimenez, O., Ambu, L., Ancrenaz, K., Andau, P., Goossens, B., Payne, J., Sawang, A., Tuuga, A. & Lackman-Ancrenaz, I. (2005) Aerial surveys give new estimates for orangutans in Sabah, Malaysia. *PLoS Biology,* **3,** 30-37.

~~Ancrenaz, M., Oram, F., Ambu, L., Lackman, I., Ahmad, E., Elahan, H., Kler, H., Abram, N.K. & Meijaard, E. (2014) Of Pongo, palms and perceptions: a multidisciplinary assessment of Bornean orang-utans Pongo pygmaeus in an oil palm context. *Oryx.*~~

Anderson, K. & Gaston, K.J. (2013) Lightweight unmanned aerial vehicles will revolutionize spatial ecology. *Frontiers in Ecology and the Environment,* **11,** 138-146.

Buckland, S.T., Anderson, D.R., Burnham, K.P. & Laake, J.L. (1993) *Distance sampling: Estimating abundance of biological populations.* Chapman and Hall, London.

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L. & Thomas, L. (2004) *Advanced Distance Sampling: Estimating Abundance of Biological Populations*. Oxford University Press, Oxford.

Buij, R., Singleton, I., Krakauer, E. & van Schaik, C.P. (2003) Rapid assessment of orangutan density. *Biological Conservation,* **114,** 103-113.

Campbell-Smith, G., Campbell-Smith, M., Singleton, I. & Linkie, M. (2011a) Apes in space: saving an imperilled orangutan population in Sumatra. *PLOS ONE,* **6,** e17210.

~~Campbell-Smith, G., Campbell-Smith, M., Singleton, I. & Linkie, M. (2011b) Raiders of the lost bark: Orangutan foraging strategies in a degraded landscape. *PLOS ONE,* **6,** e20962.~~

Chabot, D., Carignan, V. & Bird, D.M. (2014) Measuring Habitat Quality for Least Bitterns in a Created Wetland with Use of a Small Unmanned Aircraft. *Wetlands,* **34,** 527-533.

Chen, Y., Shioi, H., Montesinos, C.F., Koh, L.P., Wich, S. & Krause, A. (2014) Active detection via adaptive submodularity. *Proceedings of The 31st International Conference on Machine Learning*, pp. 55-63.

Dunn, O.J. (1964) Multiple comparisons using rank sums. *Technometrics,* **6,** 241-252.

Getzin, S., Wiegand, K. & Schöning, I. (2012) Assessing biodiversity in forests using very high-resolution images and unmanned aerial vehicles. *Methods in Ecology and Evolution,* **3,** 397-404.

Hansen, M.C., Potapov, P.V., Moore, R., Hancher, M., Turubanova, S.A., Tyukavina, A., Thau, D., Stehman, S.V., Goetz, S.J., Loveland, T.R., Kommareddy, A., Egorov, A., Chini, L., Justice, C.O. & Townshend, J.R.G. (2013) High-Resolution Global Maps of 21st-Century Forest Cover Change. *Science,* **342,** 850-853.

Hodgson, A., Kelly, N. & Peel, D. (2013) Unmanned aerial vehicles (UAVs) for surveying marine fauna: a dugong case study. *PLOS ONE,* **8,** e79556.

Jones, G.P.I.V., Pearlstine, L.G. & Percival, H.F. (2006) An Assessment of Small Unmanned Aerial Vehicles for Wildlife Research. *Wildlife Society Bulletin,* **34,** 750-758.

Koh, L.P. & Wich, S.A. (2012) Dawn of drone ecology: low-cost autonomous aerial vehicles for conservation. *Tropical Conservation Science,* **5,** 121-132.

Koops, K., Humle, T., Sterck, E.H. & Matsuzawa, T. (2007) Ground-nesting by the chimpanzees of the Nimba Mountains, Guinea: environmentally or socially determined? *American Journal of Primatology,* **69,** 407-419.

Koski, W., Abgrall, P. & Yazvenko, S. (2010) An inventory and evaluation of unmanned aerial systems for offshore surveys of marine mammals. *J. Cetacean Res. Manage,* **11,** 239-247.

~~Meijaard, E., Albar, G., Rayadin, Y., Ancrenaz, M. & Spehar, S. (2010) Unexpected ecological resilience in Bornean Orangutans and implications for pulp and paper plantation management. *PLOS ONE,* **5,** e12813.~~

Mulero-Pázmány, M., Negro, J.J. & Ferrer, M.J.o.U.V.S. (2014) A low cost way for assessing bird risk hazards in power lines: Fixed-wing small unmanned aircraft systems. *Journal of Unmanned Vehicle Systems,* **2,** 5-15.

Sasse, D.B. (2003) Job-Related Mortality of Wildlife Workers in the United States, 1937-2000. *Wildlife Society Bulletin,* **31,** 1015-1020.

Szantoi, Z., Wich, S.A., Smith, S.E. & Koh, L.P. (in review) Mapping of land cover relevant for orangutans using landsat imafery augmented with unmanned autonomous vehicle photography. *PLOS ONE*.

van Andel, A.C., Wich, S.A., Boesch, C., Koh, L.P., Robbins, M.M., Kelly, J.T. & Kühl, H.J. (in review) Locating chimpanzee nests and identifying fruiting trees with an Unmanned Aerial Vehicle *American Journal of Primatlogy*.

van Schaik, C.P., Monk, K.A. & Robertson, J.M.Y. (2001) Dramatic decline in orang-utan numbers in the Leuser Ecosystem, Northern Sumatra. *Oryx,* **35,** 14-25.

van Schaik, C.P., Priatna, A. & Priatna, D. (1995) Population estimates and habitat preferences of orang-utans based on line transects of nests. *The neglected ape* (eds R.D. Nadler, B.M.F. Galdikas, L.K. Sheeran & N. Rosen). Plenum Press, New York.

Vermeulen, C., Lejeune, P., Lisein, J., Sawadogo, P. & Bouché, P. (2013) Unmanned aerial survey of elephants. *PLOS ONE,* **8,** e54700.

Wich, S., Fredriksson, G., Usher, G., Peters, H., Priatna, D., Basalamah, F., Susanto, W. & Kühl, H. (2012) Hunting of Sumatran orang-utans and its importance in determining distribution and density. *Biological Conservation,* **146,** 163-169.

Wich, S.A., Meijaard, E., Marshall, A.J., Husson, S., Ancrenaz, M., Lacy, R.C., van Schaik, C.P., Sugardjito, J., Simorangkir, T., Traylor-Holzer, K., Doughty, M., Supriatna, J., Dennis, R., Gumal, M., Knott, C.D. & Singleton, I. (2008) Distribution and conservation status of the orang-utan (Pongo spp.) on Borneo and Sumatra: how many remain? *Oryx***,** 329-339.

Wich, S.A., Riswan, J., Refisch, J. & Nellemann, C. (2011) *Orangutans and the economics of sustainable forest management in Sumatra*. United Nations Environment Programme.

Figure legends

Fig 1: Map that shows the location of the restoration site in Sumatra. The forest layer was produced by WWF.

Fig 2: Orthomosaic of the study area. The orthomosaic was processed with Pix4Dmapper by Pix4D.

Fig 3: Photo of nests as observed from the ground (left) and from the air (right)

Fig 4~~3~~: Box plots showing the ground (a) and aerial (b) nest density for the different areas. Refor = fully reforested area, Enrich = Enrichment planted area.

Fig 5~~4~~: Maps showing the Kernel nest densities for the nests observed from the ground (a) and from the air (b).

Figure 1

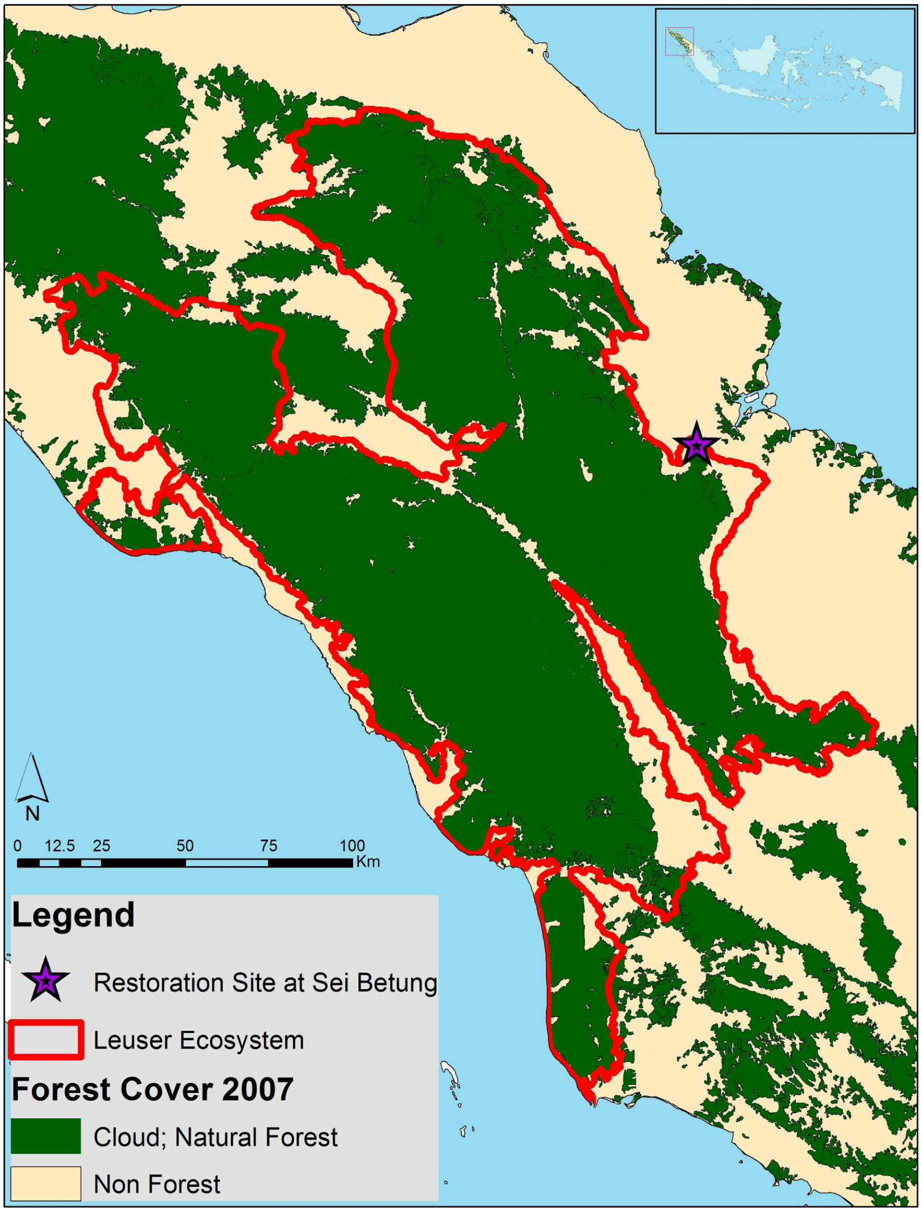
N
0 12.5 25 50 75 100
Km
Legend
Restoration Site at Sei Betung
Leuser Ecosystem
Forest Cover 2007
Cloud; Natural Forest
Non Forest

Figure 2

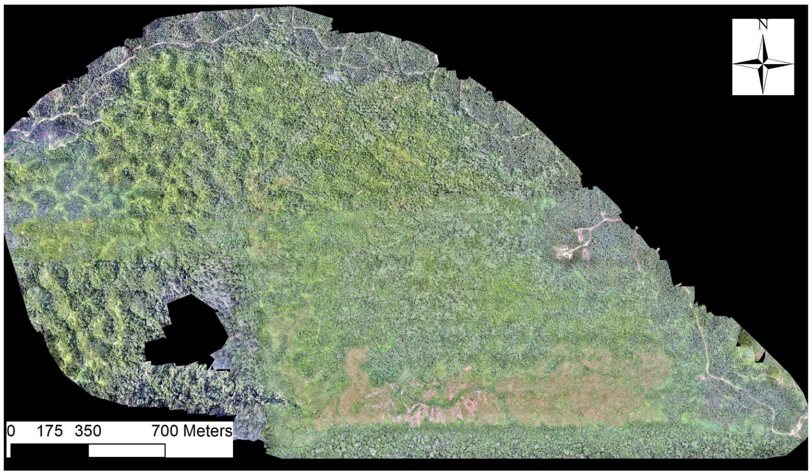

Figure 3

Formatted: Font: (Default) Arial, 12 pt

Figure ~~3~~4

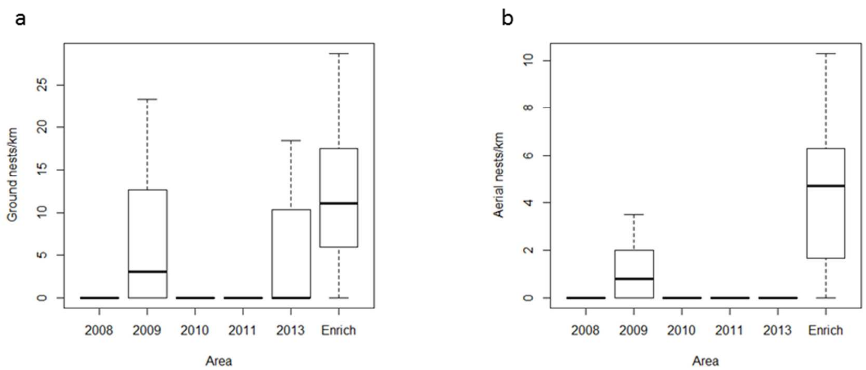
a
Ground nests/km
0
5
10
15
20
25
2008
2009
2010
2011
2013
Enrich
Area
b
Aerial nests/km
0
2
4
6
8
10
2008
2009
2010
2011
2013
Enrich
Area

Figure ~~5~~4